Japanese Laid-Open Patent Publication No. H09-120067

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[Title of the Invention] LIGHT SOURCE APPARATUS AND APPARATUS USING THE SAME

[Abstract]

[Problem]

To obtain a light beam with high efficiency, high output, and high directionality.

[Solution]

A light source apparatus is constructed so that a light source 11 is disposed at a first focal point of an elliptic mirror 12, a first diaphragm 17 and a second conical prism 14 are disposed at a second focal point, a condensing lens that condenses and emits light that has passed the first diaphragm 17 is provided, a small spherical mirror 10 is disposed facing the elliptic mirror 12, and the diameter D_A of a circle A that is a line of intersection between a plane perpendicular to the optical axis and the surface of the elliptic mirror at the first focal point of the elliptic mirror 12 is larger than a diameter D_B of a circle B that is a line of intersection between a perpendicular plane and the surface of the spherical mirror 10.

[Claims]

[Claim 1] A light source apparatus in which a first focal point of an elliptic

mirror (12) approximately matches a center of curvature of the spherical mirror (10), a light source (11) is disposed at a position proximate thereto, a first diaphragm (17) is disposed in a position proximate to a second focal position of the elliptic mirror (12), a condensing lens (13) for condensing light that has passed the first diaphragm (17) is provided, and light that has passed the condensing lens (13) is emitted,

wherein a reflective surface of the elliptic mirror (12) and a reflective surface of the spherical mirror (10) face each other along an optical axis and the reflective surface of the elliptic mirror (12) is larger than the reflective surface of the spherical mirror (10).

[Claim 2] A light source apparatus according to Claim 1, wherein at the first focal point of the elliptic mirror (12), a diameter D_A of a circle A that is a line of intersection between a plane perpendicular to the optical axis and a surface of the elliptic mirror is larger than a diameter D_B of a circle B that is a line of intersection between a perpendicular plane and the surface of the spherical mirror (10).

[Claim 3] A light source apparatus according to either Claim 1 or Claim 2, wherein a relationship between a first focal point distance f_1 of the elliptic mirror (12) and a radius of curvature R of the spherical mirror (10) satisfies $f_1>R$.

[Claim 4] A light source apparatus according to any of Claim 1 to Claim 3, wherein a depth H of the reflective surface of the elliptic mirror (12) on the optical axis satisfies a relationship $f_1 \leqq H \leqq (f_1 + f_2) / 2$ with respect to a first focal point distance f_1 and a second focal point distance f_2, and a depth of the reflective surface of the spherical mirror (10) on the optical axis satisfies a relationship $R/2 \leqq h \leqq R$ with respect to the radius of curvature R.

[Claim 5] A light source apparatus according to any of Claim 1 to Claim 4, wherein a conical prism (14) is provided proximate to the second focal point of the elliptic mirror (12), and light that has passed the conical prism and the first diaphragm (17) is condensed by the condensing lens (13).

[Claim 6] A light source apparatus according to Claim 5, wherein the conical prism (14) is a convex conical prism where an apex angle α of the incident surface or the emission surface for light is 90 to 175° or a concave conical prism where an apex angle β is 185 to 270°.

[Claim 7] A projector-type display apparatus comprising a transmission/scattering type display element (15) on which light emitted from a light source apparatus according to any of Claim 1 to Claim 6 is incident and a projection optical system that projects light that has passed the transmission/scattering type display element (15)

onto a screen or the like.

[Claim 8] A projector-type display apparatus according to Claim 7, wherein a second condensing lens (16) and a second diaphragm (18) with an aperture at approximately a focal point position of second condensing lens (16) are disposed in the projection optical system.

[Claim 9] A lighting apparatus that uses a projector-type display apparatus according to any of Claims 6, 7, and 8.

[Detailed Description]

[0001]

[Field of the Invention]

The present invention relates to the construction of a highly efficient light source apparatus. Various types of optical apparatuses in which this light source apparatus is applied, and in particular a projector-type display apparatus that uses a transmission/scattering type display element and a lighting apparatus that uses this light source apparatus are described in detail.

[0002]

[Description of Related Art]

FIG. 12 and FIG. 13 show the invention disclosed by Japanese Laid-Open Patent Publication No. H07-134295 as a first related art. This invention is a projector-type display element in which the convergence of light from a light source is improved to make more effective use of light.

[0003]

FIG. 12 is a schematic diagram showing an arrangement of a light source 11, an elliptic mirror 12, a prism 14, and a first diaphragm 17 that compose the light source apparatus. FIG. 13 shows one application of this light source apparatus, where a projector-type display apparatus 500 is constructed by combining a first condensing lens 13A, a transmission/scattering type display element 15, a second diaphragm 18, a second condensing lens 13B, and a projection lens 19.

[0004]

The prism 14 in this projector-type display apparatus is disposed at approximately a second focal point position of the elliptic mirror 12. Also, this prism is approximately conical and exhibits rotational symmetry about the optical axis. Light emitted from the light source 11 that has been reflected and condensed by the elliptic mirror is incident on the prism, is refracted by the incident surface and the emission surface of the prism and is then emitted.

[0005]

In this invention, there is insufficient distributed light in the optical axis direction for the beam produced by condensing the light emitted from the light source using the elliptic mirror, but since light is refracted by the prism to make the distributed light more uniform, there is an increase in the beam density, so that the condensing efficiency for the light source is high and a bright display can be realized.

[0006]

Also, by providing the first diaphragm 17 at a position proximate to the second focal point of the elliptic mirror, it is possible to eradicate scattered light from the light source. That is, since the light source is not an ideal point light source but instead has

a finite light emitting length (the length of the filament or the like), light that does not reach the vicinity of the second focal point of the elliptic mirror and proceeds towards the first condensing lens 13A and light has not been reflected by the elliptic mirror and has not passed the second focal point but is directed towards the transmission/scattering type display element 15 can be eradicated so that the contrast between the light and dark parts of the projected image can be improved.

[0007]

Next, the content disclosed by Japanese Laid-Open Patent Publication No. H07-5419 is described as a second related art. This invention further improves the convergence of light from a light source to make efficient use of the light. As shown in FIG. 14, a construction is used where a spherical mirror 12b is arranged on the light emission side of the elliptic mirror 12a so that its center of curvature approximately matches the first focal point of the elliptic mirror. The spherical mirror used here has a radius of curvature R that is sufficiently large compared to a first focal point distance f_1 of the elliptic mirror, a diameter of an opening in the spherical mirror is larger than the diameter of an opening in the light emission side of the elliptic mirror, and the spherical mirror is disposed so as to cover the opening in the elliptic mirror.

[0008]

Also, in these related art examples, projector-type color display apparatuses are disclosed that use a white light source, a color splitting /combining system that uses two flat dichroic mirrors of different types, and a total of three transmission/scattering-type liquid crystal display elements for the respective wavelengths RGB in a reflective-type construction. These apparatuses are small, and have improved light usage efficiency and contrast for the projected images.

[0009]

[Problems to Be Solved]

The present invention has an object of providing a small, highly efficient, and high luminance light source apparatus that could not be produced according to the related art described above. A further object is to improve the optical characteristics of a projector-type display apparatus or the like in which the light source apparatus is combined with another optical system.

[0010]

[Means to Solve the Problems]

First, the present invention provides a light source apparatus that can provide a beam with a high luminance and uniform directivity. By combining an elliptic mirror and a spherical mirror, a small, lightweight, and low cost light source apparatus is constructed. In addition, a projector-type display apparatus and lighting apparatus with high performance are constructed by combining the light source apparatus with a transmission/scattering type display element. Fundamentally, a relatively large elliptic mirror and small spherical mirror are combined so as to face each other and the spherical mirror is provided inside the elliptic mirror.

[0011]

More specifically, the present invention is a light source apparatus in which a first focal point of an elliptic mirror 12 approximately matches a center of curvature of a spherical mirror 10, a light source 11 is disposed at a position proximate thereto, a first diaphragm 17 is disposed in a position proximate to a second focal position of the elliptic mirror 12, a condensing lens 13 for condensing light that has passed the first diaphragm 17 is provided, and light that has passed the condensing lens 13 is emitted,

wherein a reflective surface of the elliptic mirror 12 and a reflective surface of the spherical mirror 10 face each other along an optical axis and the reflective surface of the elliptic mirror 12 is larger than the reflective surface of the spherical mirror 10. This construction is referred to as the first invention. Here, the relative sizes of the reflective surfaces indicate the effective areas produced when a surface perpendicular to the optical axis is projected along the optical axis. In other words, this size is a cross-sectional surface of the elliptic mirror on a surface perpendicular to the optical axis.

[0012]

Also, for this first invention, a light source apparatus is provided where at the first focal point of the elliptic mirror 12, a diameter D_A of a circle A that is a line of intersection between a perpendicular plane of the optical axis and a surface of the elliptic mirror is larger than a diameter D_B of a circle B that is a line of intersection between a perpendicular plane and the surface of the spherical mirror 10. This construction is referred to as the second invention.

[0013]

Also for the first or second invention, a light source apparatus is provided where a relationship between a first focal point distance f_1 of the elliptic mirror 12 and a radius of curvature R of the spherical mirror 10 satisfies $f_1>R$. This construction is referred to as the third invention.

[0014]

Also for the first, second or third invention, a light source apparatus is provided where a depth H of the reflective surface of the elliptic mirror 12 on the optical axis satisfies a relationship $f_1 \leqq H \leqq (f_1+f_2) / 2$ with respect to a first focal point distance f_1

and a second focal point distance f_2, and a depth of the reflective surface of the spherical mirror 10 on the optical axis satisfies a relationship $R/2 \leqq h \leqq R$ with respect to the radius of curvature R. This construction is referred to as the fourth invention.

[0015]

Also for the first, second, or fourth invention, a light source apparatus is provided where a conical prism 14 is provided proximate to the second focal point of the elliptic mirror 12, and light that has passed the conical prism and the first diaphragm 17 is condensed by the condensing lens 13. This construction is referred to as the fifth invention.

[0016]

Also for the fifth invention, a light source apparatus is provided where the conical prism 14 is a convex conical prism where an apex angle α of the incident surface or the emission surface for light is 90 to 175° or a concave conical prism where an apex angle β is 185 to 270°. This construction is referred to as the sixth invention.

[0017]

Also provided is a projector-type display apparatus including a transmission/scattering type display element 15 on which light emitted from a light source apparatus according to any of Claim 1 to Claim 6 is incident and a projection optical system that projects light that has passed the transmission/scattering type display element 15 onto a screen or the like. This construction is referred to as the seventh invention.

[0018]

Also for the projector-type display apparatus of the seventh invention, a projector-type display apparatus is provided where a second condensing lens 16 and a

second diaphragm 18 with an aperture at approximately a focal point position of second condensing lens 16 are disposed in the projection optical system. This construction is referred to as the eighth invention.

[0019]

For the seventh or eighth invention, there is provided a projector-type display apparatus where the transmission/scattering type display element 15 includes a liquid crystal resin compound structure, where nematic liquid crystals with positive dielectric anisotropy are dispersed and held inside a resin matrix, between plates provided with electrodes, and the refractive index of the resin matrix is made to match the normal refractive index (n_0) of the liquid crystals used. This construction is referred to as the ninth invention.

[0020]

A lighting apparatus that uses the projector-type display apparatus of the seventh, eighth, or ninth invention is also provided.

[0021]

[Description of Preferred Embodiments]

The following description refers to FIG. 1. The fundamental arrangement and composition are approximately the same as the related art described above. However, the most characteristic point of the present invention is a positional relationship of a light source apparatus that has the elliptic mirror and the spherical mirror as component elements. The invention is also characterized by obtaining a powerful beam with a uniform light distribution.

[0022]

The light source apparatus according to the present invention is composed of

the light source 11, the elliptic mirror 12, a spherical mirror 10, a first diaphragm, and a condensing lens, not shown, the shape of the elliptic mirror 12 is set by the first focal point distance f_1, the second focal point distance f_2, and the depth H, and the shape of the spherical mirror 10 is set by the radius of curvature R and the depth h.

[0023]

The first focal point of the elliptic mirror 12 and the center of curvature of the spherical mirror 10 approximately match, and the light source 11 is disposed at a position proximate thereto. A first diaphragm 17 is disposed at a position proximate to the second focal point of the elliptic mirror 12. The reflective surfaces of the elliptic mirror 12 and the spherical mirror 10 face one another along the optical axis. At the first focal point of the elliptic mirror 12, a diameter D_A of a circle A that is a line of intersection between a plane perpendicular to the optical axis and the surface of the elliptic mirror is larger than a diameter D_B of a circle B that is a line of intersection between a perpendicular plane and the surface of the spherical mirror 10.

[0024]

The magnitude relationship between the first focal point distance f_1 of the elliptic mirror 12 and the radius of curvature R of the spherical mirror 10 is preferably $f_1>R$. It is also preferable for the depth H of the reflective surface of the elliptic mirror 12 on the optical axis to satisfy a relationship $f_1 \leqq H \leqq (f_1+f_2)/2$ with respect to the first focal point distance f_1 and the second focal point distance f_2, and for the depth h of the reflective surface of the spherical mirror 10 on the optical axis to satisfy a relationship $R/2 \leqq h \leqq R$ with respect to the radius of curvature R.

[0025]

It is also preferable for a conical prism 14 to be provided proximate to the

second focal point of the elliptic mirror 12 and for the light that has passed the prism and the first diaphragm 17 to be condensed by a condensing lens 13. The conical prism 14 is preferably a convex conical prism where the apex angle α of the incident surface or emission surface for the light is 90 to 175° or a concave conical prism where the apex angle β is 185 to 270°.

[0026]

The spherical mirror 10 is formed of heat-resistant glass molded in a hemispherical shape, and is achieved by coating its inner surface with a cold mirror that reflects visible light but transmits infra-red light and is formed by alternately laminating a film of metal with a high reflectivity for visible light, such as aluminum, or photorefractive dielectric TiO_2, and low refractivity dielectric $Si0_2$. It is also possible to machine a metal plate in a hemispherical shape and to coat the inner surface of this metal plate with a metal film with high reflectivity for visible light. In this case, the surface precision of the surface is inferior compared to glass, but the construction is cheap and has superior heat resistance.

[0027]

The light source has a double-layer tube construction where the entire glass bulb that forms the light emitting part is covered with a spherical glass bulb, and part of this spherical glass bulb may be coated with a reflective coating. By using this kind of double-layer tube construction, the temperature of the light emitting part is stabilized, which is advantageous in stabilizing the characteristics and extending the life of the light source.

[0028]

[Action]

According to the present invention, out of the light emitted from the light source 11, the light reflected by the spherical mirror 10 is returned to the light emitting part side and is also reflected by the elliptic mirror 12 and is condensed towards the second focal point of the elliptic mirror, so that as a result, the light distribution angle is narrowed and the beam density is increased.

[0029]

In addition, light is refracted by the conical prism 14 disposed at the second focal point position of the elliptic mirror and then emitted, which further improves the beam density and increases the light usage efficiency. This action has already been confirmed for a compound mirror where the elliptic mirror 12 and the large spherical mirror 20 shown in FIG. 14 are combined, although the external diameter of the spherical mirror 20 of the related art is larger than the external diameter of the elliptic mirror 12. With a construction according to the present invention that uses the small spherical mirror 10, the volume of the light source apparatus can be reduced, which is effective in lowering cost and in lowering weight.

[0030]

In addition, the conical prism 14 that is convex or concave is disposed at the second focal point position of the elliptic mirror 12. To prevent light that has not reached the effective surface of the conical prism from reaching the condensing lens 13, it is preferable to set a first diaphragm 17 with an aperture corresponding to the effective surface of the conical prism before or after the conical prism.

[0031]

In reality, a holder that holds the conical prism 14 functions as this diaphragm. It is preferable for the diaphragm 17 to have an aperture with a suitable shape, such as a

circle, a square, an ellipse, or a rectangle, for the optical shape of the transmission/scattering type display element 15.

[0032]

By doing so, light components that propagate from the light source 11 with a finite length, the spherical mirror 10, and the elliptic mirror 12 but are not condensed near the second focal point position are removed, so that a tight beam can be formed and when the transmission/scattering type display element 15 is in a scattering state, there is a reduction in the amount of extraneous light that reaches the screen, so that the contrast can be improved.

[0033]

In particular, this effect is especially large if a means for removing scattered light, and more specifically a second diaphragm 18, is provided between the transmission/scattering type display element 15 and the screen. Unevenness in the light intensity distribution across the screen of the transmission/scattering type display element 15 due to insufficient light components at small angles to the optical axis at the second focal point position caused by use of the compound mirror composed of the spherical mirror 10 and the elliptic mirror 12 is greatly improved and the intensity distribution is made uniform by using a convex conical prism where the apex angle α is 90 to 175° or a concave conical prism where the apex angle β is 185 to 270° according to the shapes of the light source and the compound mirror.

[0034]

In view of the usage efficiency of light and the luminance distribution on the projector screen, a range of 100 to 140° for the apex angle α and a range of 220 to 260° for the apex angle β are more preferable.

[0035]

In addition, only light that has passed the convex conical prism or the concave conical prism and the first diaphragm 17 is incident on the transmission/scattering type display element 15, so that the directionality of the beam is properly adjusted. In addition, scattered light can be removed with high efficiency from the transmitted light that has passed the transmission/scattering type display element 15, so that a high contrast projected image is obtained.

[0036]

Also, it is possible to vary the apertures of the first diaphragm 17 that is set proximate to the second focal point position of the elliptic mirror 12 and the second diaphragm 18 that is set as the means for removing scattered light, so that for example when the periphery is dark and peripheral light has little effect on the screen, it will be possible to distinguish even dark points produced by the projector-type display apparatus, so that even if the aperture of the second diaphragm is narrowed and the passing amount of light is reduced, it will still be possible to make adjustments that achieve a high contrast, so that a bright and clear display image with a high contrast is obtained.

[0037]

Also, when the periphery is bright, light from the periphery is incident on the screen, so that dark parts of an image projected by the projector-type display apparatus appear somewhat bright, and in this case by opening the apertures of both diaphragms, the amount of projected light can be increased to make the screen brighter, so that the contrast can be increased and the image can be made clearer.

[0038]

[Embodiments]

First Embodiment

FIG. 2 shows a projector-type display apparatus 100 that is a first embodiment of the present invention. The specifications of the spherical mirror 10, the elliptic mirror 12, the prism 14, and the condensing lens 13 used in this embodiment are given below.

[0039]

The spherical mirror 10 is formed by fabricating a hemisphere with a radius of curvature R=9mm from one surface of a Pyrex (a registered trademark of Iwaki Glass Co., Ltd.) glass cylinder that has a diameter of 22mm and a length of 10mm so that the depth h=8mm, and then forming a hole with a diameter of 8mm for passing through an electrode of the lamp. In addition, an aluminum mirror with an SiO film as a protective film is coated on an inner spherical surface of the spherical mirror.

[0040]

The elliptic mirror 12 is produced by forming a cold mirror on an inner surface of Pyrex glass that has been machined so that the first focal point distance f_1=22mm, the second focal point distance f_2=105mm, and the depth H=27mm.

[0041]

Here, when the spherical mirror and the elliptic mirror have been disposed so that their reflective surfaces face one another along the optical axis and the first focal point of the elliptic mirror matches the center of curvature of the spherical mirror, the diameter D_A of a circle A that is a line of intersection between a plane perpendicular to the optical axis and the surface of the elliptic mirror at the first focal point is set at around 73mm and the diameter D_B of a circle B that is a line of intersection between a

perpendicular plane and the surface of the spherical mirror is set at around 18mm.

[0042]

The prism 14 is formed of BK7 glass with an apex angle of 114°, a diameter of 30mm and a height of 12mm, with an anti-reflection coating formed on the light incident surface and the light emission surface. The condensing lens is formed of plano-convex BK7, and a lens (the lens numbered 13A in FIG. 2) with a focal point distance f_A=200mm is used on the incident side of the display element and a lens (the lens numbered 13B in FIG. 2) with a focal point distance f_B=350mm is used on the emission side of the display element.

[0043]

The conical prism 14 and the first diaphragm 17 are set at the second focal point position of the elliptic mirror 12, and the various optical components described above are disposed as shown in FIG. 2. The first diaphragm is an iris diaphragm whose aperture diameter D_A is variable. The light that has passed through the display element is condensed by the second condensing lens 13B and the second diaphragm 18 is set at a position at which an image of the aperture of the first diaphragm 17 is formed so that the aperture of the second diaphragm 18 matches the image of the aperture of the first diaphragm 17. The light that has passed the aperture of the second diaphragm passes the projection lens 19 and is projected onto the screen. The second diaphragm 18 may be disposed away from the projection lens 19, but it is preferable to set the second diaphragm 18 at a pupil position of the projection lens.

[0044]

If the diameter of the aperture of the first diaphragm 17 is a, the diameter of the aperture of the second diaphragm 18 is b, the scattering angle Φ of the incident light of

the display element and the condensing angle δ showing the directivity of the projected light are set by the following expressions.

[0045]

[Expression 1]

$$\tan\Phi = a/f_A \quad \cdots\cdots \text{Equation} \quad (1)$$

$$\tan\delta = b/f_B \quad \cdots\cdots \text{Equation} \quad (2)$$

[0046]

Here, the aperture diameters a, b of the first diaphragm and the second diaphragm are simultaneously adjusted so that $\Phi=\delta$.

[0047]

A discharge emission-type metal halide lamp is used as the light source 11. The light source 11 is a DC discharge lamp with an arc emission electrode length of 3mm and a power consumption of 150W. A display part of the display element 15 is 48mm by 64mm with a 3.15 (inch) diagonal. In experiments, measurements were made with a mask with an aperture equal to the display part being disposed in place of the display element.

[0048]

With this construction, a projection lens 19 with a focal point distance of 180mm was used, an actual size image with a scale factor 1 was formed on a light scattering/transmitting screen, and the amount of projected light was measured as an image using a CCD camera. During measurement, $\Phi=\delta$ was varied in a range of 4 to 7° and each time the emission point of the lamp was moved to maximize the projected amount of light.

[0049]

For comparison purposes, the case where only the elliptic mirror 12 is used with no spherical mirror (a first comparative example) and the case where a large spherical mirror 20 is combined as shown in FIG. 9 (a second comparative example) were also measured.

[0050]

The results are shown in FIG. 3. From these results, it can be seen that compared to the conventional case where only an elliptic mirror is used, by using the spherical mirror according to the present invention, a large increase in the amount projected light was achieved, especially when $\Phi = \delta = 4$ to $5°$. An increase in the amount of projected light was also confirmed compared to the case where a conventional elliptic mirror was combined with a large spherical mirror, but by using a small spherical mirror, an equal effect or greater was obtained with a small, lightweight, and low cost design.

[0051]

In the case of a projector-type display apparatus that uses a transmission/scattering type display element, the higher the directivity of the incident light and emitted light, that is, the smaller the value of $\Phi = \delta$, the more effectively the scattered light generated by scattering display parts of the display element is removed and so is not projected onto the screen, so that a high contrast is obtained. Accordingly, from the measurement results of the above embodiment, the directivity (that is, $\Phi = \delta$ is set at a low value) of the incident light and the projected light is improved so that amount of projected light is the same as in the related art and the contrast of the projected image can be improved.

[0052]

In the present embodiment, a discharge emission-type metal halide lamp is used as the light source, but aside from such lamp, it is possible to use a xenon lamp, an electrodeless microwave discharge lamp, a filament-emission type halogen lamp, or the like.

[0053]

In particular, when an electrodeless microwave discharge lamp disclosed in SID`92 DIGEST, p.460, D. A. MacLennan et al. (Fusion System Corp.) is used, for example, it is possible to achieve a long lamp life of 10,000 hours, which is suited to use with the condensing mirror construction of the present invention. That is, with an electrodeless microwave discharge lamp, discharge element gas is sealed in a spherical glass tube such as that shown in FIG. 4 and microwaves are applied from the outside so that a non-metallic mirror may be formed directly on a hemispherical surface of the glass tube as shown in the drawing.

[0054]

Also, although a spherical mirror is disposed on a side facing the elliptic mirror along the optical axis in the present embodiment, as shown in FIG. 5 two types of spherical mirror may be disposed so as to cover both sides of the light emitting part of the lamp with the respective centers of curvature of both being inside the light emitting part. The emitted light is emitted from narrow parts where there are no spherical surface parts of the spherical mirrors and is condensed at the second focal point position by the elliptic mirror, so that a further improvement in the beam density and increase in the condensing efficiency can be expected.

[0055]

In this case, as shown in FIG. 5, a spherical mirror split in two may be mounted

on the lamp, or as shown in FIG. 6, the lamp may have a double-layer tube construction with reflective layers being formed on the surface of the outer spherical glass tube. By forming the lamp with a double-layer tube construction, the temperature of the light emitting part can be made more uniform, which can stabilize the characteristics and extend the life of the lamp.

[0056]

Any planar display element that can assume a transmitting state and a scattering state when a voltage is applied can be used as the transmission/scattering type display element used in the present invention. Specific examples of such include a dynamic scattering mode (DSM) liquid crystal display element, a liquid crystal display element that uses a compound structure of liquid crystals and resin where liquid crystals are dispersed and held inside a resin matrix, and the transmission/scattering is controlled according to whether the refractive index of the liquid crystals and the refractive index of the resin matrix match or do not match, and an element in which minute needle-like particles are dispersed in a solution and the transmission/scattering is controlled according to the applied voltage

[0057]

Out of these, a liquid crystal display element that uses a compound structure of liquid crystals and resin has a favorable optical transmission-scattering performance, can be manufactured using a similar manufacturing process to a conventional TN-type liquid crystal display element, and is easy to use since it can be driven using the same driving IC.

[0058]

For the compound liquid crystal/resin structure used as an electro-optic

functional layer of a liquid crystal display that uses a combined liquid crystal/resin structure, resin phases and liquid crystal phases are intricately formed within a space. For example, this layer is formed of liquid crystals that fill the holes in a resin matrix in which many minute holes are formed, and depending on the applied voltage, light is transmitted when the refractive index of the liquid crystals and the refractive index of the resin matrix match and is scattered when the respective refractive indexes do not match.

[0059]

More preferably, by using nematic liquid crystals with positive dielectric anisotropy and making the refractive index of the resin matrix approximately match the normal refractive index (n_0) of the liquid crystals, high transmissivity is exhibited when a voltage is applied, with parts between pixels where there are no electrodes being placed in the scattering state (so as to appear as black when projected on the screen), so that a higher contrast image is achieved even if a light blocking film is not provided between pixels.

[0060]

A liquid crystal/resin compound structure may be constructed by sealing liquid crystals inside bubbles such as microcapsules. The individual microcapsules do not need to be completely independent, and the individual bubbles of liquid crystals may be connected via narrow gaps as in a porous body. To achieve favorable electro-optic characteristics, it is preferable for the liquid crystal phases to be completely connected to compose a liquid crystal domain that is surrounded by the resin phase formed in a mesh.

[0061]

This liquid crystal/resin compound structure can be formed by mixing the liquid crystals and the material for composing the resin matrix, hardening this mixture in a solution or latex state by photo-curing, thermal curing, hardening by solvent removal, reactive curing, or the like to separate the resin matrix and place the liquid crystals in a dispersed state inside the resin matrix.

[0062]

In particular, it is preferable to use a photo-curing or thermal-curing resin as the resin since such resin can be hardened inside a sealed system, and in particular, a photo-curing resin is preferable since it can be hardened in a short time and is not affected by heat.

[0063]

More specifically, a photo-curing vinyl resin is preferably used. A photo-curing acrylic resin is illustrated, and in particular, a resin including an acrylic oligomer that undergoes polymer hardening when irradiated with light is preferable.

[0064]

As a more specific manufacturing method, cells are formed using the same type of seal material as a normal conventional TN-type liquid crystal display element, unhardened mixture of liquid crystals and a resin matrix is introduced from a fill opening, the fill opening is sealed, and then hardening is carried out by irradiation with light or by heating.

[0065]

It is also possible to supply the unhardened mixture of liquid crystals and the resin matrix onto a plate provided with electrodes, to then lay on another plate provided with electrodes and to harden the mixture by irradiation with light or the like. Also,

additives such as ceramic particles, plastic particles, glass fibers or other type of spacer for controlling the gap between the plates, a pigment, a dye, a viscosity adjusting agent, or other additive that does not adversely affect the performance of the present invention may be added to this unhardened mixture.

[0066]

When this kind of element is used, during the hardening process, by carrying out hardening by applying a sufficiently high voltage to only specified parts, it is possible to place such parts in a state that normally transmits light, so that when there is an image to be continuously displayed, an appropriate transmitting part may be formed.

[0067]

The response time of a liquid crystal display element that uses this kind of liquid crystal/resin compound structure is around 3 to 50 msec for a rise in applied voltage and around 10 to 80 msec for a fall when the voltage is removed, which makes the liquid crystal display faster than a conventional TN-type liquid crystal display element and means that the voltage-transmissivity electro-optic characteristics are also suited to driving that realizes a multilevel display. In view of the scattering performance when there is no electric field, a volume fraction ξ of liquid crystals that can operate in a liquid crystal/resin compound structure should preferably be set so that $\xi > 20\%$, with $\xi > 35\%$ being even more preferable. On the other hand if ξ is too large, the structural stability of the liquid crystal/resin compound structure deteriorates, so that $\xi < 80\%$ is preferable.

[0068]

This liquid crystal/resin compound structure is held between the plates provided with electrodes. A liquid crystal display element that uses this liquid

crystal/resin compound structure does not have favorable multiplex driving characteristics, so that when the liquid crystal display element has a large number of pixels, active elements are disposed in each pixel.

[0069]

Of course, active elements may also be disposed as necessary in an external transmission/scattering type display element. When three-terminal elements, such as TFTs (thin film transistors), are used as the active elements, a flat electrode that is shared by every pixel may be provided on the second plate provided with electrodes, but when two-terminal elements such as MIM elements or PIN diodes are used, the second plate provided with electrodes is patterned in the form of stripes.

[0070]

Also, when TFTs are used as the active elements, silicon is preferably used as the semiconductor material. In particular, polycrystalline silicon is preferable since it has low photosensitivity compared to amorphous silicon.

[0071]

Transparent electrodes are normally used as the electrodes, but in the case where a reflective liquid crystal display element is used, reflective electrodes of aluminum, silver, and the like may be used. In a projector-type display apparatus, as described above a transmissive-type liquid crystal display is normally used as a transmission/scattering type display element and an image is projected onto a screen provided separately. In this case, the display apparatus may be a front surface projection-type device (where the viewer views images from the same side of the screen as the projector-type display apparatus) or a rear surface projection-type device (where the viewer views images from a position on the opposite side of the screen to the

projector-type display apparatus)

[0072]

It is also possible to construct a reflective projector-type display apparatus that uses a reflective-type liquid crystal display element that uses reflective electrodes or has a reflective layer provide on a rear of the element, with the emitted light being guided to an incident side of the display element. The transmission/scattering type display element can be used as a transmission/scattering type display element with a flat electrode across the entire surface, as a transmission/scattering type display element with simple patterned electrodes, and also as a projector-type display apparatus or as a lighting apparatus.

[0073]

For example, if the construction of the apparatus shown in FIG. 1 is disposed so as to be embedded in a wall, ceiling, or the like, it is possible to dim the lighting at high speed without changing the color. Also, if the construction of the apparatus shown in FIG. 1 or FIG. 5 is disposed so as to be embedded in a wall, ceiling, or the like, it is possible to dim lighting at high speed without changing the color, or to dim lighting while also changing the color.

[0074]

In addition, although a single transmission/scattering type display element 15 is used in the present embodiment, it is possible to use a plurality of transmission/scattering type display elements 15 for respective colors to produce a full color display.

[0075]

It is also possible to achieve a color display by forming an RGB mosaic color

filter on each pixel of a single transmission/scattering type display element 15 and applying RGB image signals to each color pixel. In the case where transmission/scattering type display elements are provided for the respective colors, it is possible to use a construction where the light is projected after being combined using dichroic mirrors, dichroic prisms, or the like or a construction where the colored light is projected separately and is combined on the screen, but if the light is combined and then projected, only one optical axis is used, which is advantageous in applications where a small device size and portability are required.

[0076]

Second Embodiment

An example of a projector-type display apparatus 200 that uses three transmission/scattering type display elements (numbered 15B, 15G, and 15R in the drawings) for the respective colors R, G, and B is shown in FIG. 7.

[0077]

It should be noted that although the condensing lenses 13A and 13B (13BB, 13BG, 13BR) are disposed separately before and after the display element in the first embodiment and the second embodiment, it is possible to dispose a condensing lens on only the incident side or the emission side of the display element. Also, the second diaphragm 18 that functions as a scattered light removing system may be placed before or after the projection lens and may even be provided inside the projection lens.

[0078]

Third Embodiment

An example of a projector-type display apparatus 300 that uses a single reflective-type liquid crystal display element 25 in which pixel electrodes on one side of

the transmission/scattering type display element are realized by reflective electrodes is shown in FIG. 8. FIG. 8 is a plan view, while FIG. 9 is a side elevation. In this case, the incident light is inclined by an angle of 4 to 10° with respect to a normal for the reflective electrode surface of the display element, and regular reflected light that has passed the second diaphragm 18 is projected on the screen by the projection lens 19.

[0079]

By using a reflective display element, compared to a transmissive type, the light passes through the transmission/scattering liquid crystal material layer in both directions, so there is a large improvement in scattering performance at the same driving voltage. As a result, the projected image has improved contrast.

[0080]

The above arrangement also assists in miniaturization of a projector-type display apparatus. In particular, an example of a projector-type color display apparatus 400 provided with three transmission/scattering type display elements (35R, 35G, and 35B) for the respective colors R, G, and B is shown by a plan view in FIG. 10 and a side elevation in FIG. 11. By using this construction, the dichroic mirrors 41, 42 are commonly used as a color splitting system and a color combining system, so that compared to the transmissive-type projector-type display apparatus 200 shown in FIG. 7, the apparatus can be easily miniaturized.

[0081]

[Effect of the Invention]

The present invention is extremely small and lightweight but can produce a beam with a high output, high efficiency, high directivity, and high uniformity. When incorporated in a projector-type display apparatus that is one example application, it is

possible to obtain a projected image with high luminance and high contrast. The present invention can also be applied in a variety of other ways without losing the effect of the invention.

[Brief Description of the Drawings]

[FIG. 1] FIG. 1 is a block diagram showing a first example construction of a light source apparatus according to the present invention.

[FIG. 2] FIG. 2 is a block diagram showing a first example construction of a projector-type display apparatus according to the present invention.

[FIG. 3] FIG. 3 is a characteristics graph showing measurement results for projector-type display apparatuses according to a first embodiment of the present invention and the related art.

[FIG. 4] FIG. 4 is a block diagram showing a second example construction of a light source apparatus according to the present invention.

[FIG. 5] FIG. 5 is a block diagram showing a third example construction of a light source apparatus according to the present invention.

[FIG. 6] FIG. 6 is a block diagram showing a fourth example construction of a light source apparatus according to the present invention.

[FIG. 7] FIG. 7 is a block diagram showing a second example construction of a projector-type display apparatus according to the present invention.

[FIG. 8] FIG. 8 is a plan view showing a third example construction of a projector-type display apparatus according to the present invention.

[FIG. 9] FIG. 9 is a side elevation showing a third example construction of a projector-type display apparatus according to the present invention.

[FIG. 10] FIG. 10 is a plan view showing a fourth example construction of a projector-type display apparatus according to the present invention.

[FIG. 11] FIG. 11 is a side elevation showing a fourth example construction of a projector-type display apparatus according to the present invention.

[FIG. 12] FIG. 12 is a block diagram showing a first example construction of a light source apparatus according to the related art.

[FIG. 13] FIG. 13 is a block diagram showing a first example construction of a projector-type display apparatus according to the related art.

[FIG. 14] FIG. 14 is a block diagram showing a second example construction of a light source apparatus according to the related art.

[Reference Numerals]

10: SPHERICAL MIRROR

11: LIGHT SOURCE

12: ELLIPTIC MIRROR

13, 13A, 13B, 13G, 13R, 13BB, 13BG, 13BR: CONDENSING LENS

14, 14a, 14b: CONICAL PRISM

15, 15B, 15G, 15R, 25, 35B, 35G, 35R: TRANSMISSION/SCATTERING TYPE DISPLAY ELEMENT

17: FIRST DIAPHRAGM

18: SECOND DIAPHRAGM

19: PROJECTION LENS

41, 42, 41a, 42a, 41b, 42b: DICHROIC MIRROR

M1, M2: MIRROR

TRANSLATION OF DRAWINGS

FIG. 3

スクリーン光束「任意単位」 - SCREEN FLUX (AT ARBITRARY POSITION)

集光角 – CONVERGING ANGLE

実施例１… FIRST EMBODIMENT (ELLIPTIC MIRROR AND SMALL SPHERICAL MIRROR)

比較例１… FIRST COMPARATIVE EXAMPLE (ELLIPTIC MIRROR)

比較例２… SECOND COMPARATIVE EXAMPLE (ELLIPTIC MIRROR AND LARGE SPHERICAL MIRROR)